Radiation Protection Dosimetry
Vol. 84, Nos. 1–4, pp. 387–391 (1999)
Nuclear Technology Publishing

SCREENING OF ABNORMAL LiF:Mg,Cu,P GLOW CURVES

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Abstract — A process to screen electronically abnormal LiF:Mg,Cu,P glow curves in routine dosimetry is proposed. The method is based on the fact that when a glow curve is normalised to a part of the integral of the glow curve it loses its dependence on the magnitude of the exposure. This characteristic allows a glow curve from a dosemeter exposed in the field to be compared with an 'ideal' glow curve from the same dosemeter. A difference curve is generated from the differences between the normalised 'ideal' and the normalised field curves. This difference curve can be used to identify the abnormal characteristics of the field-generated glow curve and, since both normalised curves are essentially the same, the anomalies can be resolved by reconstructing the field curve to match the 'ideal' curve.

INTRODUCTION

To analyse and compare glow curves from detectors in the field with an 'ideal' glow curve, a technique is needed that is independent of the magnitude of the exposure (Figure 1). Such a technique is proposed by normalising the glow curves in two ways: normalising the curves to the integral of the signal in the FWHM (full width half maximum) interval, and normalising the curves to the integral of the signal in the interval between two fixed channels. By normalising each channel of the glow curve to an integrated part of the glow curve, the response of each of the glow curve channels demonstrates independence from the magnitude of the exposure dose. This is true for normalisation to the integral of the response between the FWHM points and the integral of the response between a fixed range of channels.

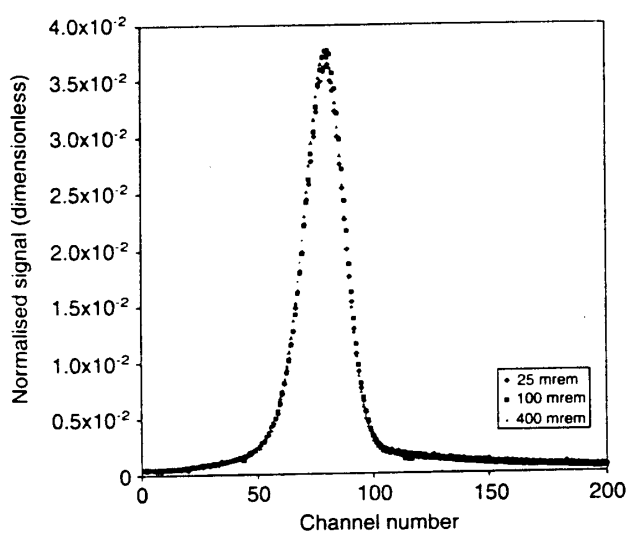

Figure 1. Graphs of the raw data normalised to the integral of the interval between two fixed points (channels 69 and 90) in the raw data curves. The fact that all three curves are virtually equal demonstrate their independence of the magnitude of the exposure.

PROCESS

The methodology proceeds in the following logical sequence:

1. The glow curve is obtained and smoothed by removing any outliers

An outlier (Figure 2) (Y_i) is defined as:

$$\frac{y_i - y_i^0}{y_{max}} > 0.025$$

where:

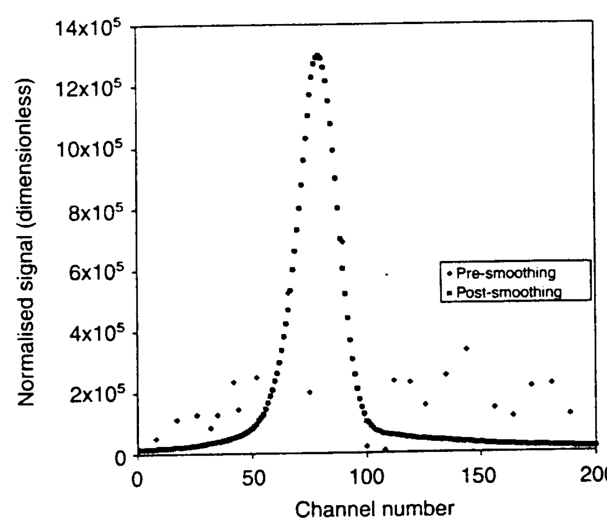

Figure 2. Curves showing the data before outliers are removed and after outliers are removed and the data is smoothed.

$y_i^0 = 0.5 \times (y_{i-1} + y_{i+1})$

An outlier is removed by replacing y_i with y_i^0.

2. Determine the background baseline and subtract the background from the glow curve

The background is described by two lines derived by linear regression using the first ten points of the glow curve to fit the line in the region preceding the peak and the last ten points of the glow curve to fit the line in the region following the peak (Figure 3). The background is determined for each channel from these straight lines and subtracted from the glow curve.

3. Evaluate the background signal

If the ratio of the integral of the background signal to the total signal is larger than 0.25, the error message 'BACKGROUND EXCEEDS TOLERANCE' is given. The glow curve is rejected.

4. Estimate the glow curve noise level

The noise is estimated by comparing the spectra before and after smoothing:

$$S = \sum_{i=1}^{200} (y_i - y'_i)/y^2_{max}$$

If the noise exceeds 10% of the total integral, the error message 'NO REJECT THE CURVE' is given and the glow curve is rejected.

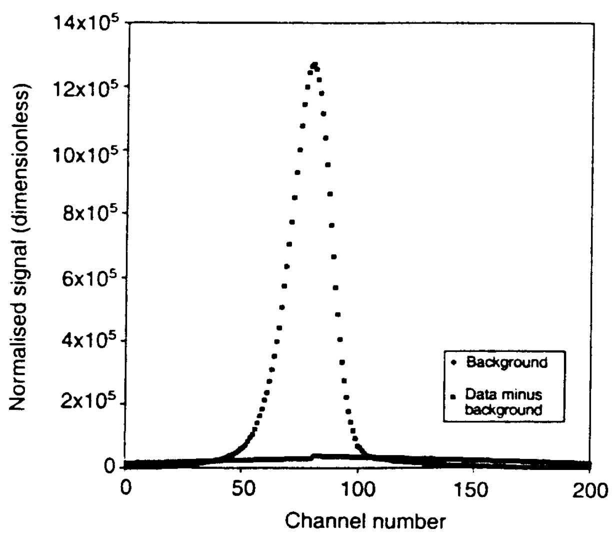

Figure 3. Curves showing the background calculated from the raw data of the 400 mrem exposure and the resulting curve when the background is subtracted from the raw data.

5. Check for saturation

If five or more channels contain equal signals (Figure 4), these channels are identified as 'SATURATED'; otherwise, channels are identified as 'OK'. This problem can possibly be corrected by reconstructing the curve using the characteristics from the 'ideal' curve.

6. Check for incomplete glow curve

If the minimum in the last 10 channels is not less than the minimum in the glow peak (Figure 5), the error message 'INCOMPLETE GLOW CURVE' is given. This problem can possibly be corrected by reconstructing the curve using the characteristics from the 'ideal' curve.

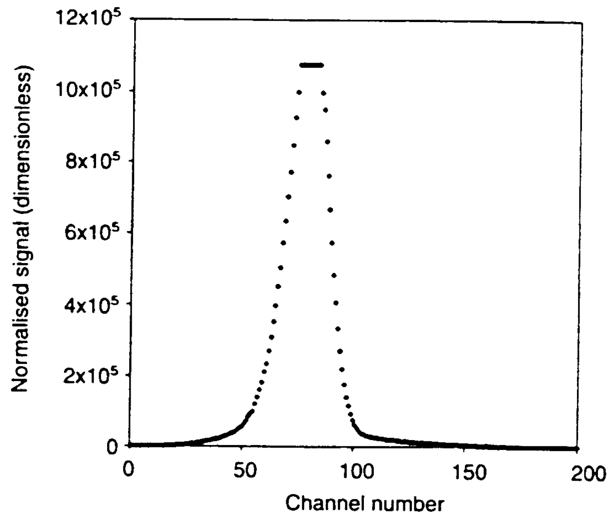

Figure 4. Curve showing a saturated glow curve, seen in the plateau region near the maximum, resulting from the readout system becoming saturated during the readout cycle.

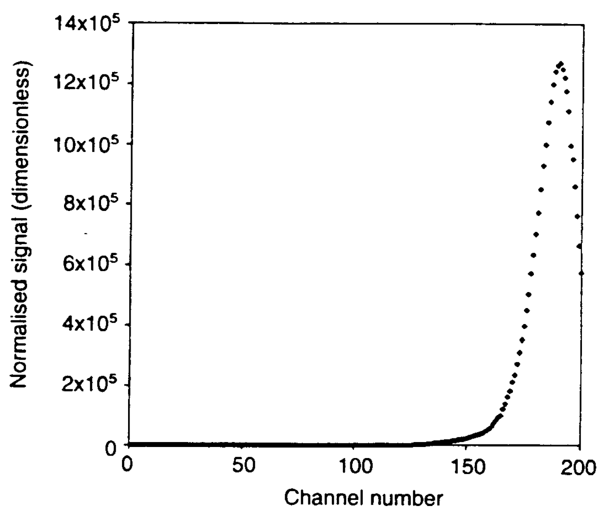

Figure 5. Curve showing the result of an incomplete glow curve, demonstrated by the cut-off of the glow curve at the high temperature end.

7. Evaluate the signal in the region preceding the main peak

If, in the region preceding the dosimetric peak (Figure 6), the integral of the signal preceding the main peak exceeds 10% of the total integral of the 'ideal' signal, the error message 'SIGNAL IN THE REGION PRECEDING THE PEAK IS EXCESSIVE' is given. This problem can possibly be corrected by reconstructing the curve using the characteristics from the 'ideal' curve.

8. Evaluate the signal in the region following the main peak

If, in the region following the dosimetric peak (Figure 7), the integral of the signal following the main peak exceeds 10% of the total integral of the 'ideal' signal, the error message 'SIGNAL IN THE REGION FOLLOWING THE MAIN PEAK IS EXCESSIVE' is given. This problem can possibly be corrected by reconstructing the curve using the characteristics from the 'ideal' curve.

9. Normalise the curves to the integral of the signal in the FWHM interval and determine its characteristics

The glow curve is normalised by dividing the value of each channel by the integral between the FWHM, giving a defining shape that is independent of the total signal (Figure 1).

The characteristics determined are: total signal, maximum signal value and channel position, half maximum signal and channel positions on both sides of the peak, field width at the half maximum points, and the slopes and intercepts of the lines tangent to the curve at the half max points.

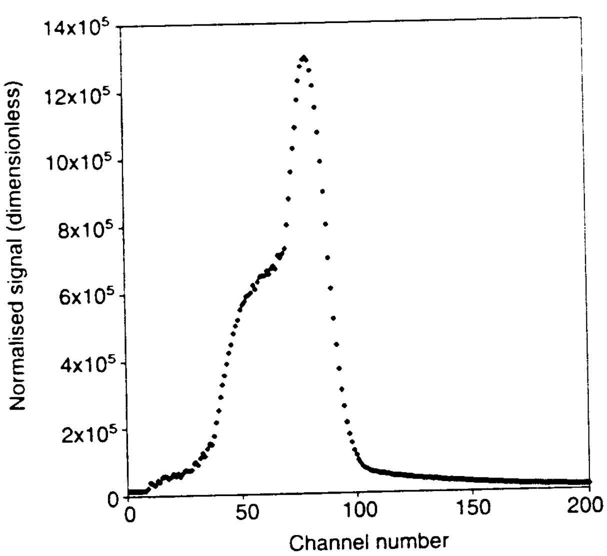

Figure 6. Curve demonstrating excessive signal at the low temperature of the glow curve preceding the main glow peak, due perhaps to the non-radiation-induced luminescence from a foreign substance on the dosemeter.

10. Normalise the curves to the integral of the signal in the interval between two fixed channels and determine its characteristics

It is possible that the FWHM of a field curve is not available because of corruption, so normalising to a fixed width that is about the same as the half maximum points interval is proposed. The fixed width of the channels is chosen to be approximately equal to the half maximum points in the previous step. The characteristics determined are: total signal, maximum signal value and channel position, half maximum signal and channel positions on both sides of the peak, field width at the half maximum points, and the slopes and intercepts of the lines tangent to the curve at the half maximum points.

For new dosemeters being introduced into a population of field dosemeters, Steps 1 through 10 only are performed and the resulting characteristics are recorded as part of each TL element's calibration record, along with the Element Correction Coefficient (ECC). These characteristics are then used as the basis for the 'ideal' curve for that chip in future field comparisons.

For dosemeters returned for evaluation after exposure in the field, abnormal curves are identified and rejected; curves capable of being reconstructed are so done. The process continues through the following steps.

11. The difference between the 'ideal' curve and the field curve is determined

The difference between the field curve and the ideal curve is calculated for each channel and plotted (Figures

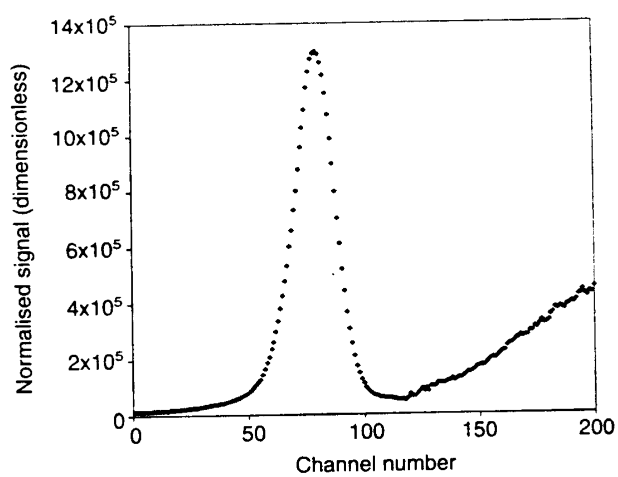

Figure 7. Curve demonstrating the condition of excessive signal at the high temperature (IR) end of the glow curve.

8 through 13). If the integral of the differences is more than a specified amount (20%, for example) of the integral of the ideal curve, the following error message is given: 'THE MAGNITUDE OF THE SUM OF THE DIFFERENCES IS TOO LARGE, IGNORE THIS CURVE'. The integral of the differences is given by:

$$D = \sum_{i=1}^{200} (y_i - y'_i)/y^2_{max}$$

If the integral of the differences exceeds the specified magnitude, each individual characteristic of the field curve is examined and compared to the 'ideal' curve. A characteristic that is found to fall outside a pre-set range is corrected to equal the 'ideal' characteristic. The integral of the differences is again calculated and an estimate of the exposure is obtained where previously the curve would have been rejected.

KEY FEATURES

The method used here is independent of the magnitude of the TL signal, so that after normalisation, doses of 25 mrem will appear the same as doses several times

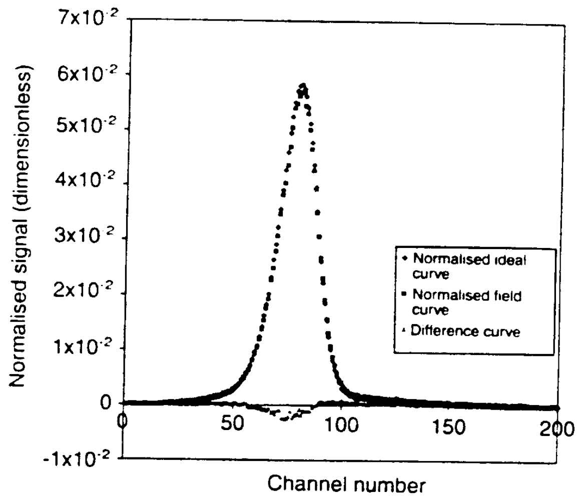

Figure 8. Graph showing the normalised 'ideal' curve, 400 mrem, the normalised field curve and the curve that shows the differences between the two for each channel. The difference curve is used for comparison with abnormal glow curves.

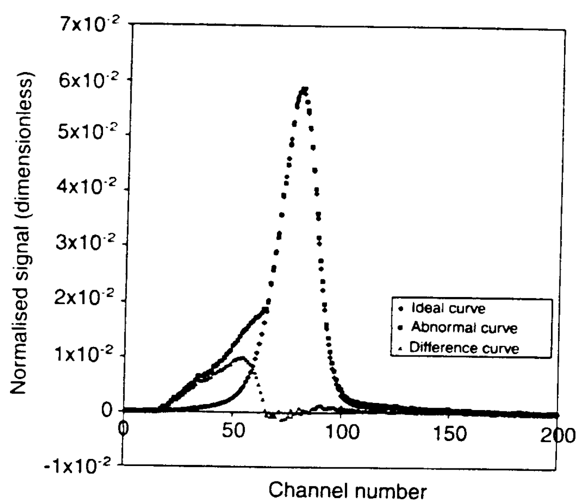

Figure 9. Graph showing the normalised 'ideal' curve, 400 mrem, the curve with an excessive signal in the low temperature region before the dosimetry peak (Figure 6), and the curve showing the differences between the two curves for each channel. The difference between the normal difference curve (as in Figure 8) and the distinctive form of this abnormal difference curve should be evident.

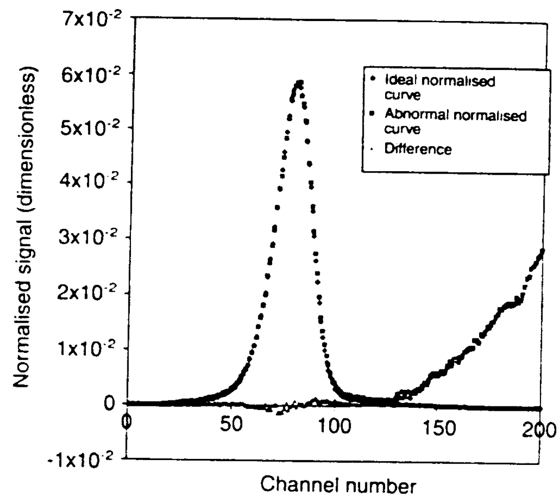

Figure 10. Graph showing the normalised ideal curve, the curve with excessive signal at the high temperature (IR) end of the spectrum (Figure 5) and the difference between the two. The shape of difference curve is distinctly different from the ideal difference curve.

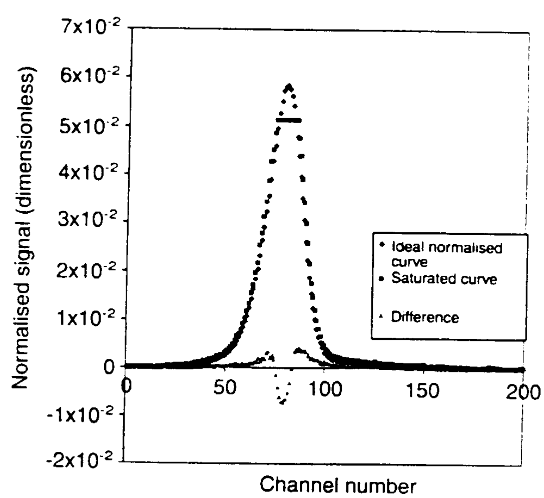

Figure 11. Graph showing the normalised ideal curve, the curve with a saturation plateau and a difference curve showing the differences between each channel of the other two curves. The distinctive shape of the difference is apparent when compared with the normal difference curve.

higher. This enables use of stored 'ideal' curves as a basis for comparison.

Because the evaluation is based on the difference between two slightly dissimilar curves, rather than on the field dosemeter curve alone, errors are magnified and more readily detectable.

The system is quite robust because each dosemeter is compared against its own ideal curve, eliminating any false negatives due to inherent differences between dosemeters.

CONCLUSION

This automated methodology offers a precise and robust glow curve evaluation technique that is both quantitative, in that it is based on strict mathematical comparisons, and qualitative, in that the printed glow curves indicate to the trained eye the reason for failure of the glow curve. Its automation makes it suitable for large scale dosimetry, yet it offers sufficient detail to satisfy the analytical needs of the health physicist.

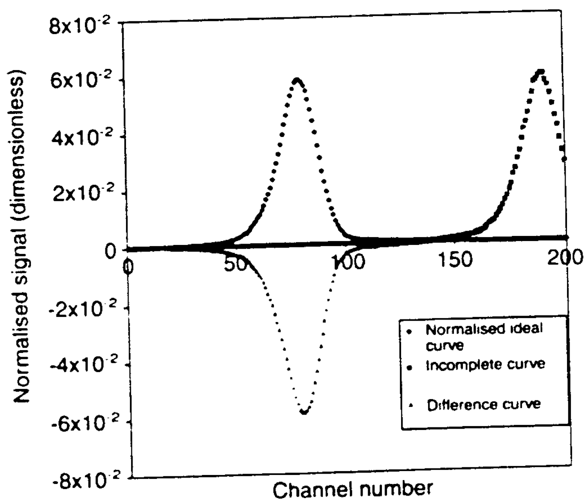

Figure 12. Graph showing the normalised ideal curve, the curve with the dosimetric peak cut off, and the curve showing the differences between the two for each channel. The distinctive two peak difference curve, one positive and one negative, is a trait of this abnormal curve.

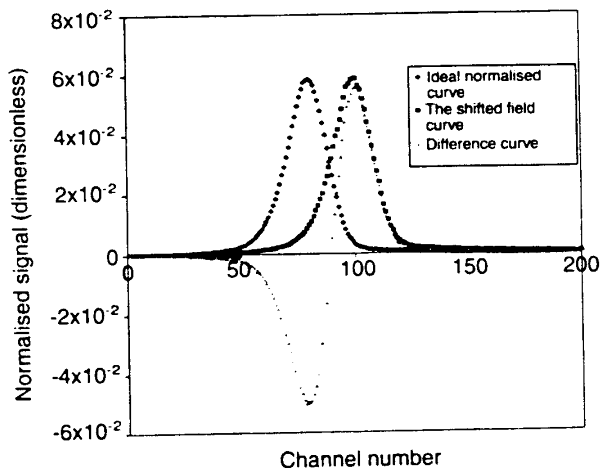

Figure 13. Graph showing the normalised ideal curve, the curve with peak shifted 20 channels, and the curve showing the differences between the two curves. The twin peak distribution is typical and changes with the amount of shift of the peak.